

INDOOR AIR QUALITY ASSESSMENT

**Dr. Fredrick N. Sweetsir Elementary School
104 Church Street
Merrimac, Massachusetts**



Prepared by:
Massachusetts Department of Public Health
Bureau of Environmental Health Assessment
Emergency Response/Indoor Air Quality Program
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Background/Introduction

At the request of Marc Barry, Head Custodian, the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA) provided assistance and consultation regarding indoor air quality concerns at the Sweetsir Elementary School (SES) in Merrimac, Massachusetts. The request was made to provide recommendations to improve indoor air quality within the building.

On May 27, 2003, a visit to conduct an indoor air quality assessment was made to this school by Cory Holmes, Environmental Analyst in BEHA's Emergency Response/Indoor Air Quality (ER/IAQ) Program. Mr. Barry accompanied Mr. Holmes during the assessment.

The school is a one-story, brick/concrete building on cement slab constructed in the early 1960's. An addition was constructed in 1994. The school is made up of general classrooms, specialty classrooms, library, art room, music room, computer room, cafeteria, kitchen, teachers' work rooms, activity room, gymnasium and office space. Windows throughout the building are openable.

Methods

Air tests for carbon dioxide, temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor, Model 8551. Moisture content of water damaged ceiling materials in the small group room was measured with a Delmhorst, BD-2000 Model, Moisture Detector with a Delmhorst Standard Probe.

Results

This school houses approximately 400 students in grades K–6, and has a staff of approximately 40. Tests were taken during normal operations at the school and results appear in Table 1.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were below 800 parts per million of air (ppm) in twelve of seventeen areas surveyed, indicating adequate ventilation the majority of areas tested in the school. As indicated in Table 1, a number of classrooms had open windows during the assessment. Open windows can greatly reduce carbon dioxide levels.

Ventilation is provided by rooftop air handling units (AHUs) (Picture 1). Fresh air is distributed by AHUs via ductwork connected to ceiling-mounted air diffusers and/or diffusers located on cabinets along the interior wall of classrooms (Pictures 2 & 3). The amount of fresh air drawn into AHUs is controlled by an actuator motor that adjusts movable louvers. On the day of the assessment, all AHUs were functioning, however, the louvers on some of the AHUs were closed, limiting airflow (Picture 4). The condition of the AHUs and ductwork appears to be poor. Rooftop AHUs were severely corroded, weathered and/or physically damaged (Pictures 1, 5 & 6). The condition of AHUs is discussed in further detail in the Microbial/Moisture Concerns section of this assessment.

The mechanical exhaust ventilation system consists of ducted ceiling and wall-mounted exhaust vents which return air to the rooftop AHUs. A number of exhaust vents were blocked by desks, cabinets, and other furniture (Picture 7). In order for exhaust ventilation to function as designed, vents must remain free of obstructions. Without proper exhaust ventilation, indoor air pollutants can build up and lead to indoor air quality/comfort complaints.

To maximize air exchange, the BEHA recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy. In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. The date of the last balancing of these systems was not available at the time of the assessment. It is recommended that HVAC systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994).

The Massachusetts Building Code requires that each room have a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being

exceeded. When this happens, a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, see [Appendix I](#).

Temperature readings ranged from 71° F to 77° F, which were within the BEHA comfort guidelines. The BEHA recommends that indoor air temperatures be maintained in a range of 70° F to 78° F in order to provide for the comfort of building occupants. A number of temperature control/comfort complaints were expressed by occupants throughout the building. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. In addition, it is difficult to control temperature and maintain comfort without operating the ventilation equipment as designed (e.g. AHU louvers shut, exhaust vents obstructed).

The relative humidity measured in the building ranged from 44 to 48 percent, which was within the BEHA recommended comfort range. The BEHA recommends a

comfort range of 40 to 60 percent for indoor air relative humidity. Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

As previously noted, the casings of AHUs were corroded. The top of the AHU in Picture 5 is concave, due to water pooling. The assessment occurred on a day of moderate rainfall. Pooling water was noted on top and seeping down the side of one of the AHUs. The interior of this AHU was examined and found to have standing water due to leakage around metal access panels in the housing (see Picture 6). Accumulated debris (dirt, dust, etc.) and porous insulation material inside the AHU can provide a medium for mold growth when it becomes wet. If these materials become colonized with microbial growth, spores can be distributed to occupied areas via the ventilation system.

A survey of the building exterior revealed a number of potential sources of water penetration:

- Holes/cracks were observed in exterior walls (Pictures 8 & 9).
- Caulking around exterior window frames and wall panels was crumbling or missing (Pictures 10 & 11).
- Shrubbery and other plants exist in close proximity to foundation walls (Picture 12).

The growth of roots against the exterior walls can bring moisture in contact with wall brick and eventually lead to cracks and/or fissures in the foundation below ground

level. Over time, this process can undermine the integrity of the building envelope and provide a means of water entry into the building through capillary action through foundation concrete and masonry (Lstiburek & Brennan, 2001).

- Picture 13 shows a damaged downspout that empties rainwater against the foundation. In some cases catch basins were pitched toward the building, resulting in water pooling against the foundation (Picture 14).
- Piles of saturated plant debris were seen on the roof (Picture 15). This material can hold water on the roof where repeated freezing and thawing during winter months can damage the roof membrane and lead to water penetration.

In each of these instances, water can eventually penetrate into the SES interior. Repeated water penetration can result in the chronic wetting of building materials and potentially lead to microbial growth. In addition large wall cracks/holes may provide a means of egress for pests/rodents into the building.

The ceiling in the small group room is made of gypsum wallboard (GW) and was water stained reportedly due to a roof leak that was repaired (Picture 16). In order for building materials to support mold growth, a source of water exposure is necessary. Identification and elimination of water moistening building materials is necessary to control mold growth. GW with increased moisture content over normal concentrations may indicate the possible presence of mold growth. Moisture testing of the water damaged GW in the small group room was tested and found to not be moistened. Microbial growth in GW in this area would be limited due to a lack of water.

A water cooler is located on carpeting in the teacher's workroom. To avoid water damage to carpeting and/or prevent potential mold growth, a water-resistant material such

as plastic or rubber matting should be installed beneath water fountains and/or water coolers. The American Conference of Governmental Industrial Hygienists (ACGIH) recommends that carpeting be dried with fans and heating within 24 hours of becoming wet (ACGIH, 1989). If carpets are not dried within this time frame, mold growth may occur. Water-damaged carpeting cannot be adequately cleaned to remove mold growth. The application of a mildewcide to moldy carpeting is not recommended.

In a number of classrooms, spaces between the particleboard sink countertop and backsplash were noted (Picture 17). Improper drainage or sink overflow could lead to water penetration. If the seam is not watertight, water can collect behind countertops and/or cabinets. Like other porous materials, if wetted repeatedly they can provide a medium for mold growth.

Other Concerns

Several other conditions were noted during the assessment, which can affect indoor air quality. Cleaning products were found in floor level cabinets and on counter tops in several classrooms. Cleaning products contain chemicals (such as bleach or ammonia-related compounds), which can be irritating to the eyes, nose and throat. These items should be stored properly and out of the reach of students.

Several classrooms contained dry erase boards and dry erase board markers. Materials such as dry erase markers and dry erase board cleaners may contain volatile organic compounds (VOCs), such as methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve (Sanford, 1999), which can be irritating to the eyes, nose and throat.

In an effort to reduce noise from sliding chairs, tennis balls have been sliced open and placed on chair legs. Tennis balls are made of a number of materials that are a source of respiratory irritants. Constant wearing of tennis balls can produce fibers and off-gas VOCs. Tennis balls are made with a natural rubber latex bladder, which becomes abraded when used as a chair leg pad. Use of tennis balls in this manner may introduce latex dust into the school environment. Some individuals are highly allergic to latex (e.g. spina bifida patients) (SBAA, 2001). It is recommended that the use of materials containing latex be limited in buildings to reduce the likelihood of symptoms in sensitive individuals (NIOSH, 1997). A question and answer sheet concerning latex allergy is attached as Appendix II (NIOSH, 1998).

Finally, the filters installed in rooftop AHUs provide minimal filtration of respirable particulates. In order to decrease aerosolized particulates, disposable filters with an increased dust spot efficiency can be installed. The dust spot efficiency is the ability of a filter to remove particulates of a certain diameter from air passing through the filter. Filters that have been determined by ASHRAE to meet its standard for a dust spot efficiency of a minimum of 40 percent would be sufficient to reduce airborne particulates (Thornburg, D., 2000; MEHRC, 1997; ASHRAE, 1992). Note that increased filtration can reduce airflow produced by the unit by increased resistance (called pressure drop). Prior to any increase of filtration, each piece of air handling equipment should be evaluated by a ventilation engineer to ascertain whether they can maintain function with more efficient filters.

Conclusions/Recommendations

In view of the findings at the time of the visit, the following recommendations are made:

1. Based on the age, physical deterioration and availability of parts of the HVAC system, the BEHA strongly recommends that an HVAC engineering firm -fully evaluate the ventilation system.
2. To maximize air exchange, the BEHA recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy independent of classroom thermostat control.
3. Consider consulting a heating, ventilation and air conditioning (HVAC) engineer concerning the calibration of fresh air control dampers school-wide.
4. Inspect exhaust motors and belts for proper function, repair and replace as necessary.
5. Remove all blockages from supply and exhaust vents.
6. Consider having ventilation systems re-balanced every five years by an HVAC engineering firm.
7. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).

8. Conduct thorough inspection of the building envelope and repair/replace missing or damaged caulking and seal all cracks and holes in walls to prevent water penetration.
9. Consider having exterior brick re-pointed and waterproofed to prevent water intrusion.
10. Replace/repair damaged downspouts and install elbows in a manner to direct rainwater away from the building.
11. Remove accumulated plant debris from roof. Inspect roof drains regularly for proper drainage.
12. Remove plant growths against the exterior wall/foundation of the building to prevent water penetration. Trim trees in rear of building away from brickwork.
13. Seal areas around sinks to prevent water-damage to the interior of cabinets and adjacent wallboard. Disinfect areas of microbial growth with an appropriate antimicrobial as needed. Consider replacing with one-piece, molded countertops.
14. Place a water impermeable barrier (e.g. rubber or plastic) beneath water coolers or relocate to non-carpeted areas.
15. Store cleaning products properly and out of reach of students.
16. Discontinue the use of tennis balls on chairs to prevent latex dust generation.
17. Examine the feasibility of installing more efficient filters in rooftop AHUs.
18. In order to maintain a good indoor air quality environment on the building, consideration should be give to adopting the US EPA document, “Tools for Schools”. This document can be downloaded from the Internet at <http://www.epa.gov/iaq/schools/index.html>.

19. For further building-wide evaluations and advice on maintaining public buildings, see the resource manual and other related indoor air quality documents located on the MDPH's website at <http://www.state.ma.us/dph/beh/iaq/iaqhome.htm>.

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Picture 1



**Rooftop AHUs, Note Dark Stains on Ductwork and Near Top of AHU
Indicating Rust/Corrosion**

Picture 2



Air Diffuser on Side of Classroom Cabinet

Picture 3



Ceiling-Mounted Air Diffuser

Picture 4



AHU Fresh Air Intake Louvers Shut

Picture 5



Water Pooling/Corrosion on Top of AHU

Picture 6



Moisture/Debris on Floor of AHU

Picture 7



Wall-Mounted Exhaust Vent Obstructed by Cart

Picture 8



Hole in Exterior Wall Covering, Pen Inserted to Illustrate Depth of Hole

Picture 9



Damaged Wall Material Exposing Interior Matrix

Picture 10



Missing/Damaged Caulking Along Base of Wall Panel

Picture 11



Compromised Caulking around Window Frame

Picture 12



Shrubbery in Close Proximity to Exterior/Foundation Wall

Picture 13



Damaged Downspout Note Depression from Water Pooling Against Foundation

Picture 14



Downspout Catch Basin that was Pitched *Toward* Building

Picture 15



Large Pile of Plant Debris on Roof Against Wall

Picture 16



Water Damaged GW Ceiling in Small Group Room

Picture 17



Spaces Between Sink Countertop and Backsplash

TABLE 1
Indoor Air Test Results – Merrimac Sweet Sir Elementary School

May 27, 2003

Location	Carbon Dioxide (*ppm)	Temp. (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation		Remarks
						Supply	Exhaust	
Outside (Background)	377	57	69					Rainy – cloudy Light breeze
Room 3	773	75	68	15	Y	Y	Y	Vent off Cleaning product on counter top
Art Room	493	74	48	0	Y	Y	Y	Window/door open, spaces countertop/sink, cleaning product under sink, items hang from CT, tennis balls
Room 19	606	75	46	15	Y	Y	Y	Window/door open Spaces countertop
Room 21 Activity Room	512	73	46	0	Y	Y	Y	
Room 22	616	74	46	20	Y	Y	Y	3 CT Cleaning product on counter top
Room 23	742	75	47	21	Y	Y	Y	Window/door open, guinea pig, cleaning product on counter top
Room 17 Computer Room	544	77	45	1	Y	Y	Y	20 occupants left approximately 10 min, 25 computers, no AC
Teacher's Room	743	74	44	1	Y	Y	Y	Water cooler on carpet, photocopiers, exhasut vent on opposite side of room

* ppm = parts per million parts of air

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred 600 - 800 ppm = acceptable > 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 1
Indoor Air Test Results – Merrimac Sweet Sir Elementary School

May 27, 2003

Location	Carbon Dioxide (*ppm)	Temp. (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation		Remarks
						Supply	Exhaust	
Library	774	74	45	20	Y	Y	Y	Window/door open 1 CT
Parent Center	764	75	47	5	Y	Y	Y	Door open 1 CT
Room 8	877	72	45	0	Y	Y	Y	Supply vent blocked
Room 9	1032	71	48	19	Y	Y	Y	Supply partially blocked Tennis balls
Room 10	1234	71	48	20	Y	Y	Y	Spaces countertop, tennis balls, spray cleaning product under sink
Room 5	814	72	49	0	Y	Y	Y	Supply vent partially blocked
Small Group	795	72	48	0	N	Y	Y	Ceiling water stained, tennis balls, roof leak repaired, gypsum ceiling-dry
Teacher's Room	854	72	48	6	Y	Y	Y	
Cafeteria	725	71	47	100+	Y	Y	Y	

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						Supply	Exhaust	
Perimeter (Outside)								Gutter/down spouts dislodged and catch basins pitched toward bldg., hole in wall panel (outside parent center), missing/damaged caulking windows/wall panels, cracked damaged wall material, shrubbery in close proximity to building
Rooftop Notes								Water pooling/accumulated plant debris, water damaged/pooling on AHU casings, interior leaks, several exhaust vents not operating (on repair list from town electrician)

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Temperature - 70 - 78 °F

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